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Sustainability assessment of residential building architecture in terms of Nikos A. Salingaros's criteria

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Abstract. Modern 'sustainable' architecture requires clear criteria for the comprehensive assessment of its forms. An American theorist N. A. Salingaros deduced a number of laws governing the creation of a stable and adaptive architectural form that follows the structure of natural forms. These patterns serve as the basis for the authors of the article to derive criteria for evaluating architectural objects. The criteria are framed in the system, the testing of which was carried out in the analysis of residential complexes of the city of Yekaterinburg in 2010–2020.

1. Introduction

Globalization leads architecture to unification and arbitrary changeability of forms, loss of individuality and harmony [1]. Increasingly, users and critics forget about the status of architecture as an objective-spatial activity to create harmonious forms, reducing the building only to a set of engineering solutions. Attempts to strengthen sustainability are not always successful, since there are no clear-cut criteria for sustainable architecture. One of the leading ideologists of sustainable shaping is N. Salingaros (b. 1952), an apprentice of the prominent British architect Ch. Alexander [2, 3]. Their ideas for sustainable design are relevant and promising [4, 5, 6], but are not yet known enough [7]. They are not accepted by all architects and urbanists, who require even more specificity in the design [5]. The article defines and systematizes the criteria for sustainable architecture based on the approach of N. Salingaros, followed by a brief test in assessing modern residential architecture in Russia.

2. Materials and methods

The article develops the ideas of N. Salingaros presented in the book 'Algorithmic Sustainable Design: Twelve Lectures on Architecture' [8]. Here, in an appeal to the fundamental laws of the organization of matter and information, the principles of the formation of stable architecture close to the physical and mental arrangement of a man are substantiated. Not reducing scientific data, but presenting it to readers step by step, N. Salingaros offers mathematical algorithmic design solutions. He criticizes modernist and deconstructivist architecture, creating one-dimensional and inhumane forms [9]. The principles of creating sustainable adaptive architectural forms, including in relation to residential buildings, are given in the book rather briefly and were not developed by other authors. The structure of the book is quite complicated for direct design use. Thus, the first three parts are an intensive immersion in architectural mathematics and physics, which quite sharply turns into a general theoretical block, within which self-repetitions arise. Themes of universal scaling, references to the geometry of the living world, in particular, fractals, and a number of other fragments are uttered twice.



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The most productive is the lack of unambiguous options for implementing the principles of organizing a stable form, the freedom of a specialist in choosing tools and techniques. Such a choice is dictated to a much greater extent by the features of the site and residents [8], turning architecture into a kind of 'membrane' between nature and civilization.

From the whole set of principles deduced by the architect, we will focus on the ideas of scaling and combinatorial complexity, for which it is possible to find a quantitative equivalent. Their clarity provides certain limitations in the design, helping the architect to get away from random or arbitrary ideas. By virtue of this, they can serve as criteria for assessing sustainable morphogenesis.

The empirical basis of the work is the material on 15 projects of residential complexes in Yekaterinburg (Russia), built in 2015–2020. Paradoxically, residential buildings are less often conceptualized from the standpoint of organic and sustainable architecture [10], but in the period after the pandemic we can expect an increase in interest in this approach in this particular segment.

3. Discussion

3.1. Ensuring the complexity of a form, according to N. Salingaros

According to N. Salingaros, we design by computing. Only calculations will bring architecture to sustainability. The first steps are mastering universal scaling, the Fibonacci series, the 'rule of 3' and other techniques that provide a holistic view of the projected object in the unity of all its elements and scales, from layout and facade to molding and window frames.

Why then are design algorithms needed? It is they that take a specialist away from the 'memory of a typology', the knowledge of which they received during their training. If an architect was taught 'modernist', then the 'memory of the typology' is not so easy to eradicate; a person makes certain design actions almost without accountability, without controlling themselves and, thereby, not allowing themselves to deviate from stereotypes. 'The algorithm allows us to be independent of memory, making us more creative.'

The living world and 'living' architecture have a complex multi-level device. N. Salingaros interprets their forms as information 'clots' arranged in a special way. For their existence and, especially, development, they need a certain complexity because the same units of information do not generate movement. This complexity assumes the existence of different levels of organization of the form – its different scales, symmetries, centers, self-similarity and other characteristics. A complex form is born step by step from simpler forms as a result of the action of various forces within it caused by these qualities. Based on this, in the first chapter of the work of N. Salingaros, five principles of the 'living' form, including the architectural one, are deduced (Table 1).

N. Salingaros offers design based on arithmetic sequences, for example, arithmetic recursion (Fibonacci series) to follow the scaling order. He explains the rule of increasing and decreasing scales, saying that the scale step is $1/3$ or 30%. Another suggested sequence is exponential. When raising an exponent to some power, a series of numbers is formed that are used to create the form.

Universal scaling gives certain restrictions or rules for creating any form in architecture. The sizes of any element in architecture must be compared with the arithmetic sequence. Universal scaling involves a hierarchy of scales, where small and large scales create a single adaptive whole.

Biophilia as a general scientific term speaks of a person's innate desire to seek connections with wildlife [11]. Specifying it, N. Salingaros shows the connection at the genetic level of a man and the geometry of biological structures. He claims that human health depends on the surrounding shapes and geometries. The proximity of the architectural forms surrounding a man to biological structures makes it easy for them to process these forms, and therefore contributes to their well-being. It is important to understand that we are not talking about a primitive set of architectural elements, but about the concept of creating entire buildings and cities that obey the rules of biophilia. Ideas are already gaining followers [12, 13]. Combinatorial complexity is associated by N. Salingaros with the work of the nervous system and perception. He claims that the brain perceives information by combining it, combinations are perceived by a person more easily than monotonous repetition, which initiates

comparison causing stress. Combinatorial complexity is determined by the number of identical parts, which are divided into groups that are convenient for perception.

Table 1. Organization principles providing scaling and combinatorial complexity in architecture (according to N. Salingaros).

<i>Nº</i>	<i>Principle</i>	<i>Description</i>
1	Recursion and Fibonacci sequence	a) Algorithmic design. As a method of selecting the right decisions.
		b) The laws of morphogenesis. Generating a form based on genetic information.
		c) Sequences (arithmetic and exponential). Adapted Fibonacci sequence: 1, 3, 8, 21, 55, 144, 377, 987, 2584, ... 1/3 or 30 % scale step.
2	Universal scaling	Consists in a hierarchy of scales, where small and large scales create a single form.
3	Biophilia	Taking into account the relationship of man and the geometry of biological structures at the genetic level. Architecture directly affects the human condition.
4	Scaling and division	Parallels the development of the embryo, which through the division of the cells that form the group, turns into a mature person.
5	Combinatorial complexity	The brain perceives information, combining it, the combinations are perceived by a person easier than monotonous repetition, which causes stress.

The principles given are not something new and unique; they have long been used by architects. It seems that today they are more relevant, both for external (urbanization, ecology, pandemic) and internal (lack of a ‘big style’, erosion of an aesthetic scale) reasons. An example of the implementation of the principle of universal scaling in modern conditions is the building at 1399 Park Avenue in New York, USA, from the architectural bureau Hill West Architects (Figure 1). The division of the facades and the difference in volumes create an alternative to standard rectangular high-rise buildings dating back to modernism. However, there is also a discrepancy with the principles of N. Salingaros, for example, monotony in the rhythm of windows and almost complete absence of small scales.



Figure 1. 1399 Park Avenue. New York, USA. 2020. Arch. Hill West Architects. Source: <https://www.archdaily.com/>.



Figure 2. ‘A House at Sea’. Bergeggi, Italy. 2019. Arch. Studio Daniele et al. Source: <https://www.archdaily.com/>.

‘A House at Sea’ (Italy) complies with the principles of sustainability in terms of scale and combinatorial complexity (Figure 2). The windows are designed so that they form groups by means of non-monotonous repetition. This building has a drawback – it lacks small-scale details.

3.2. *Scaling and combinatorial complexity in the system of criteria for assessing architecture*

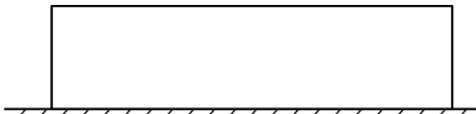
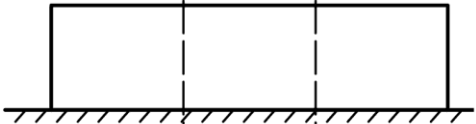
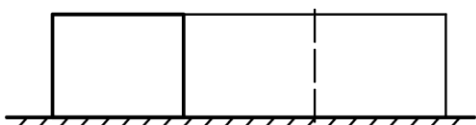
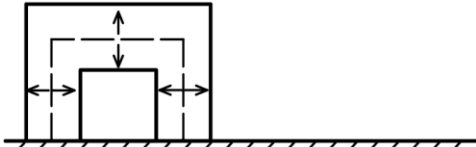
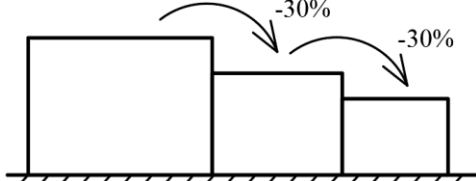
We believe that the use of sequences is not always possible due to the design and technical requirements for architecture. Compliance with numerical sequences is difficult to bring into line with the existing standards. This is of great importance directly in the development of project documentation and in the construction process.

Biophilia and men’s dependence on the geometry of biological structures are intuitively clear, but they cannot be translated into quantitative equivalents, which means that they cannot become parameters for assessing architectural objects according to the criteria for the stability of their shape. Such a ‘translation’ is possible for the following principles, deduced by N. Salingaros.

3.2.1. *Scaling hierarchy (a system of a combination of elements of different scales).* This explains the proportions of all elements of an object relative to each other. According to the laws of the physical world, a stable form requires a minimum of three levels of scale. N. Salingaros makes a projection this rule on architecture.

3.2.2. *The formation of small forms by dividing the large ones using a universal scale step, approximately equal to 1/3.* It can be used in dividing the total volume of the building, including when designing residential complexes. We presented the process of universal scaling in Table 2.

Table 2. The process of universal scaling.

<i>Nº</i>	<i>Description, according to N. Salingaros</i>	<i>Visualization</i>
1	Initial choice of form (search for the optimal template for further development): vertical / horizontal direction of construction	
2	Conditional form division into modules	
3	Selection of the defining element from which further scaling will be performed	
4	Correction of the selected form element: decrease / increase	
5	Selection of the defining element from which further scaling will be carried out	

3.2.3. Small-scale grouping and medium-sized formation. Elements of the building are grouped at all levels of scale, thereby forming a larger scale. E.g.: windows are grouped vertically, then they are grouped horizontally. This is the movement from the window (small scale) to the whole building (largest scale) (Figure 3).

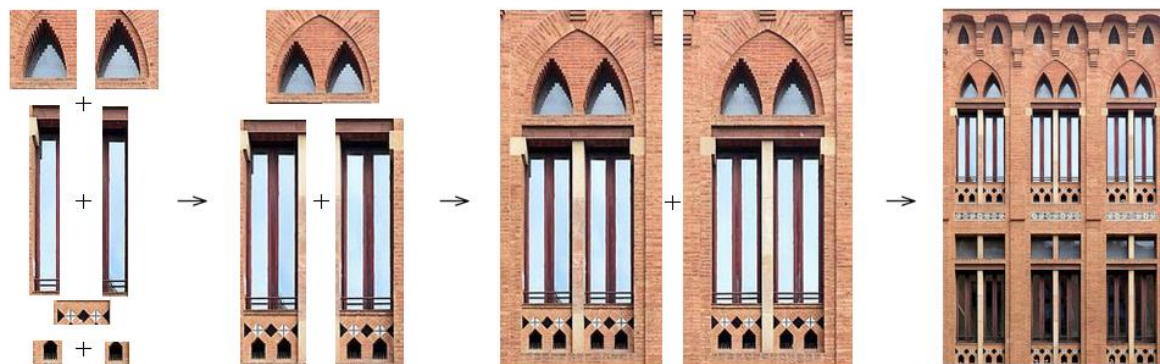


Figure 3. Maternity home. Arch. C. Oliveras, G. Guitart et al. Barcelona, Spain. 1883. Source: <https://www.flickr.com/>.

3.2.4. Variability on a small scale. Violation of monotony on a small scale can create textures, ornaments. The right choice of finishing materials significantly increases the architectural stability of the entire building. The more heterogeneous and textured is the lining, the more rigid is the object.

3.2.5. Refusal of monotonous repetition. On a medium scale, the rejection of monotony can be manifested through groupings, and on a small scale, it can be done by the variability of elements of the same type. This point is unifying for the previous two. It characterizes the synthesis of the two criteria.

4. Results

Based on the analysis of the principles for creating a sustainable architectural form, Table 3 is compiled. This is a system for assessing the sustainability of an architectural form in the aspect of scaling. It involves the criterion assessment of two points or four subpoints. The corresponding points are awarded for the compliance of the architectural object with a particular item.

15 residential complexes built in Yekaterinburg over the past five years have been examined (Figure 4). The analysis showed that only in 20% of residential complexes the forms correspond to the highest stability rating, another 20% have an average score, and the majority (60%) have a low rating. Figure 8 shows part of the evaluated buildings, which are divided into groups according to the assessment of their forms.

Table 4 presents the results of the evaluation of architectural forms in the projects of residential buildings in the city of Yekaterinburg, built in 2015–2020. In general, architects' attempts to get away from monotony are noticeable – if only because it is not remembered by accommodation buyers. Moreover, scaling more often has a superficial, decorative character and does not lead to a fundamental departure from modernist shaping. There is no dynamics over the years (the movement from less stable forms to more stable). There is a priority of economic considerations of developers and architects to architectural shaping.

Table 3. A system for assessing an object according to the criteria of a sustainable architectural form.

Group of principles		Criterion	Compliance points	Note
1	Scaling	1.1 Scaling hierarchy	2	Presence of three levels of scale: large, medium, small
			1	Presence of two levels of scale: large and medium or large and small
			0	Presence of one level of scale: large
		Total (max)	2	Choosing one option
		1.2 Small scale grouping	2	Medium and small scales are grouped
			1	Only medium scales are grouped
			1	Only small scales are grouped
			0	Scales are not grouped
		Total (max)	2	Choosing one option
2	Combinatorial complexity	2.1 Lack of monotony	1	Violation of monotonous repetition
			0	Presence of monotonous repetition
		Total (max)	1	Choosing one option
		2.2 Small scale variation	2	Small scale variation (finishes and ornaments)
			1	Small scale variation (finishes)
			1	Small scale variation (ornaments)
			0	Lack of variation
		Total (max)	2	Choosing one option
Total (max)		7		

Group 1 (7-6 points)



Group 2 (5-4 points)



Group 3 (3-0 points)

**Figure 4.** Residential complexes in Yekaterinburg. 2015–2020.

Table 4. A system for assessing an object according to the criteria of a sustainable architectural form.

Label	Name of residential complex	Year of construction	Criteria				Total points	Group
			1.1	1.2	2.1	2.2		
a	RC «Armada»	2019	2	2	1	2	7	1
b	RC «Club House Tikhvin»	2015	2	2	1	1	6	
c	RC «Club House Riviera»	2019	2	2	1	1	6	
d	RC «Moskovsky Kvartal»	2020	1	2	1	0	5	2
e	RC «Yantarnaya Dolina»	2020	2	1	1	0	4	
f	RC «Clever Park»	2019	2	2	0	0	4	
g	RC «Trinity»	2018	0	0	0	1	1	3
h	RC «Sedmoye nebo»	2017	1	1	1	0	3	
i	RC «Repin park»	2019	1	1	1	0	3	

5. Conclusion

The study confirmed that the principles deduced by N. Salingaros can be used as parameters of the stability of buildings and objects. Practical testing showed that these parameters can be systematized and applied to the scale of entire cities and countries. However, the derived criteria for scaling and combinatorial complexity relate only to a part of the characteristics of a sustainable architecture, so in the future it is necessary to refine the system for assessing the stability of architectural forms.

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